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Supporting Information for

Cassini Plasma Observations of Saturn's Magnetospheric Cusp

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Introduction

Included in the online supporting material are figures of some of the events mentioned in the main article (Figures S1-S3), a presentation of an ion energy pitch angle dispersion observation (Figure S4), as well as tables of the full results of the calculated distances to the reconnection site and plasma composition (Tables S1-S2).

Text S1.

The cusp observations are presented in the following order: 24SEP08, 24JUL13, and 17AUG13 (Figures S1-S3).

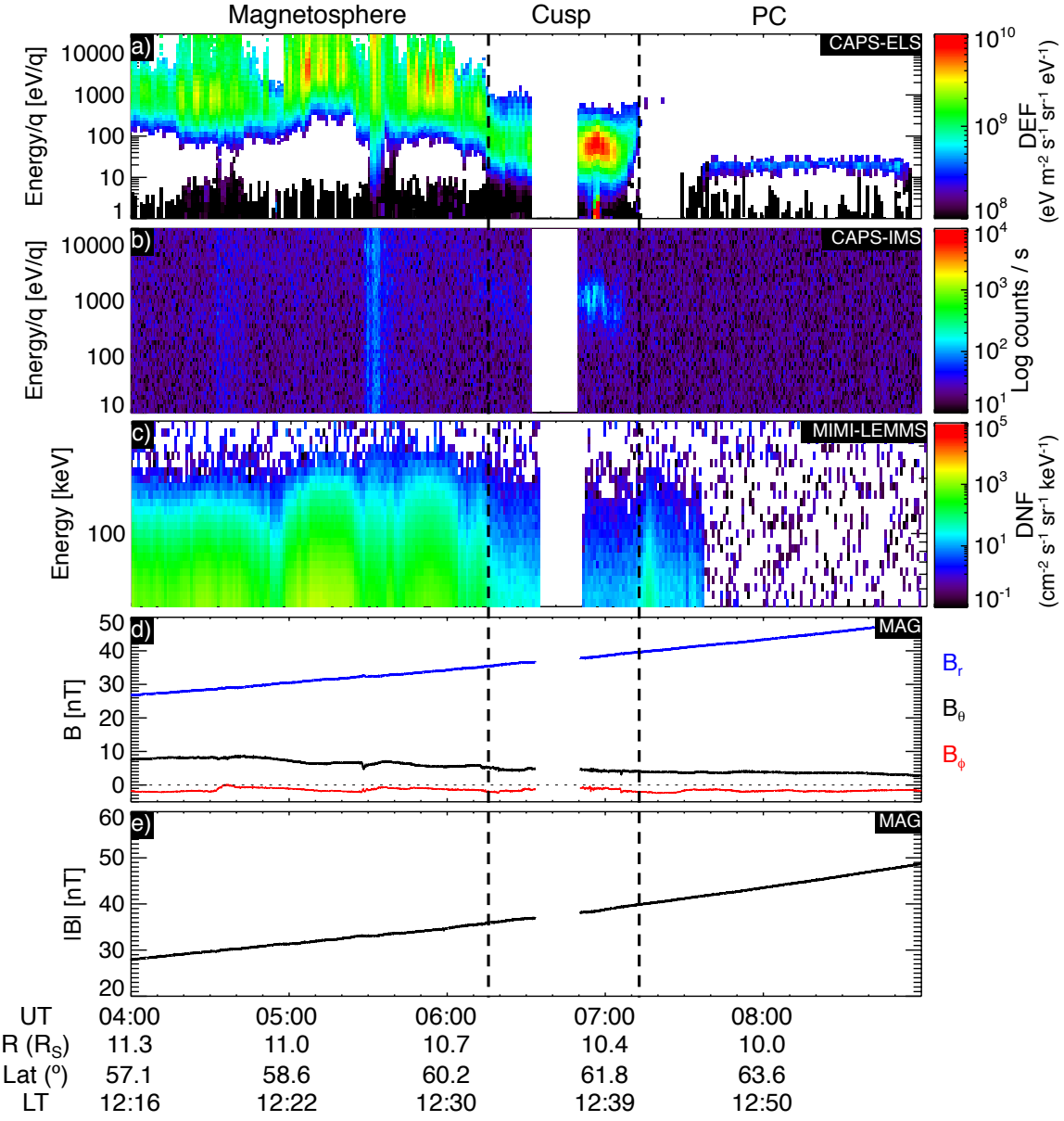

Figure S1. Cusp observations from the 24th of September 2008, with the cusp observed at 06:50-07:20 UT. Panels: a) electrons from CAPS-ELS, b) ions from CAPS-IMS, c) high-energy electrons from MIMI-LEMMS, d) the three components of the magnetic field in KRTP coordinates from MAG and e) the magnitude of the magnetic field also observed by MAG. In panel a), whilst in the polar cap, the electron fluxes at ~10 eV are unremoved spacecraft photoelectrons. The increase in flux at 05:30 UT in CAPS-IMS (b) are due to energetic electrons penetrating the CAPS housing and increasing the noise level.

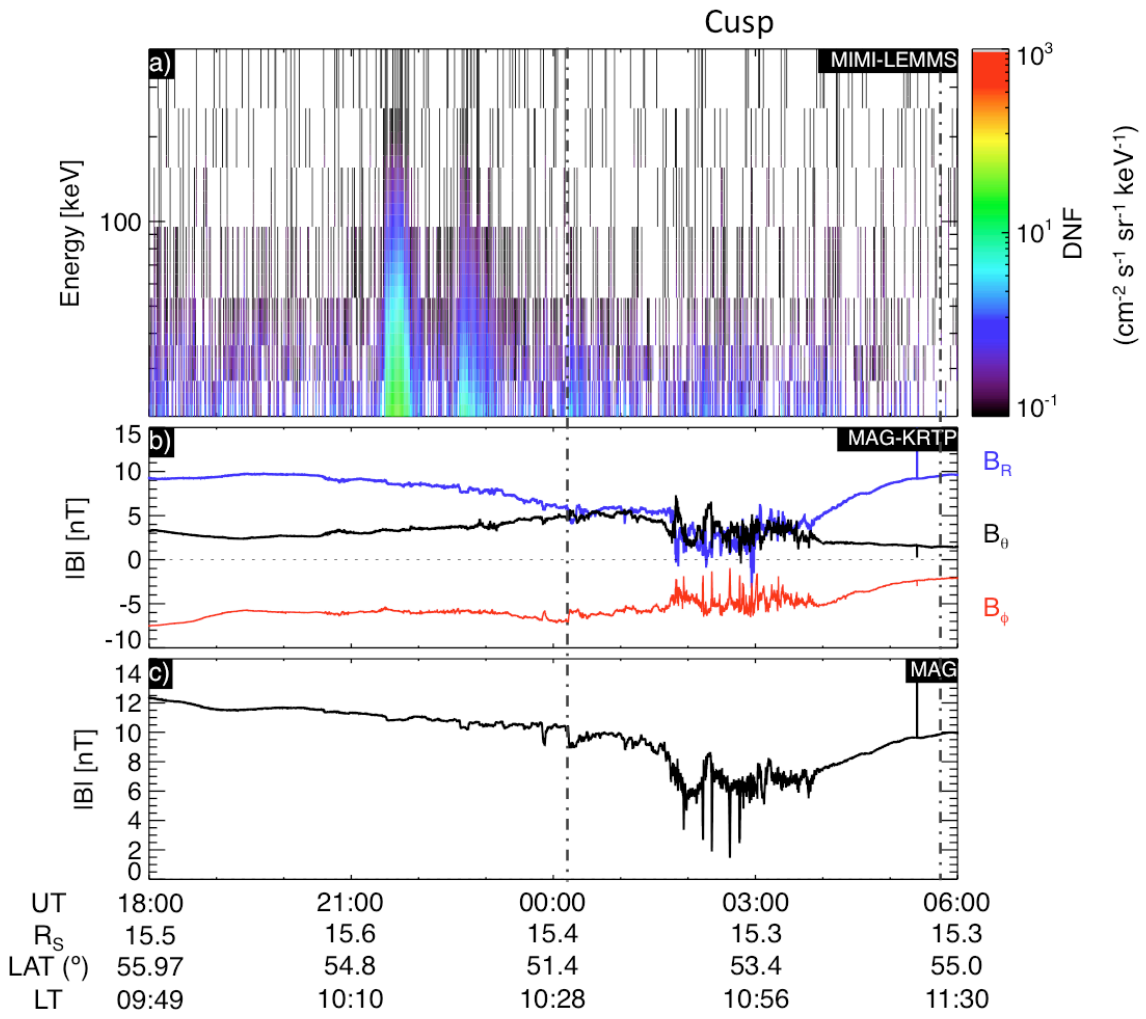

Figure S2. Cusp observations from the 24th of July 2013. The data are presented in the following order: a) high-energy electrons from MIMI-LEMMS, b) the three components of the magnetic field in KRTP coordinates from MAG and c) the magnitude of the magnetic field also observed by MAG.

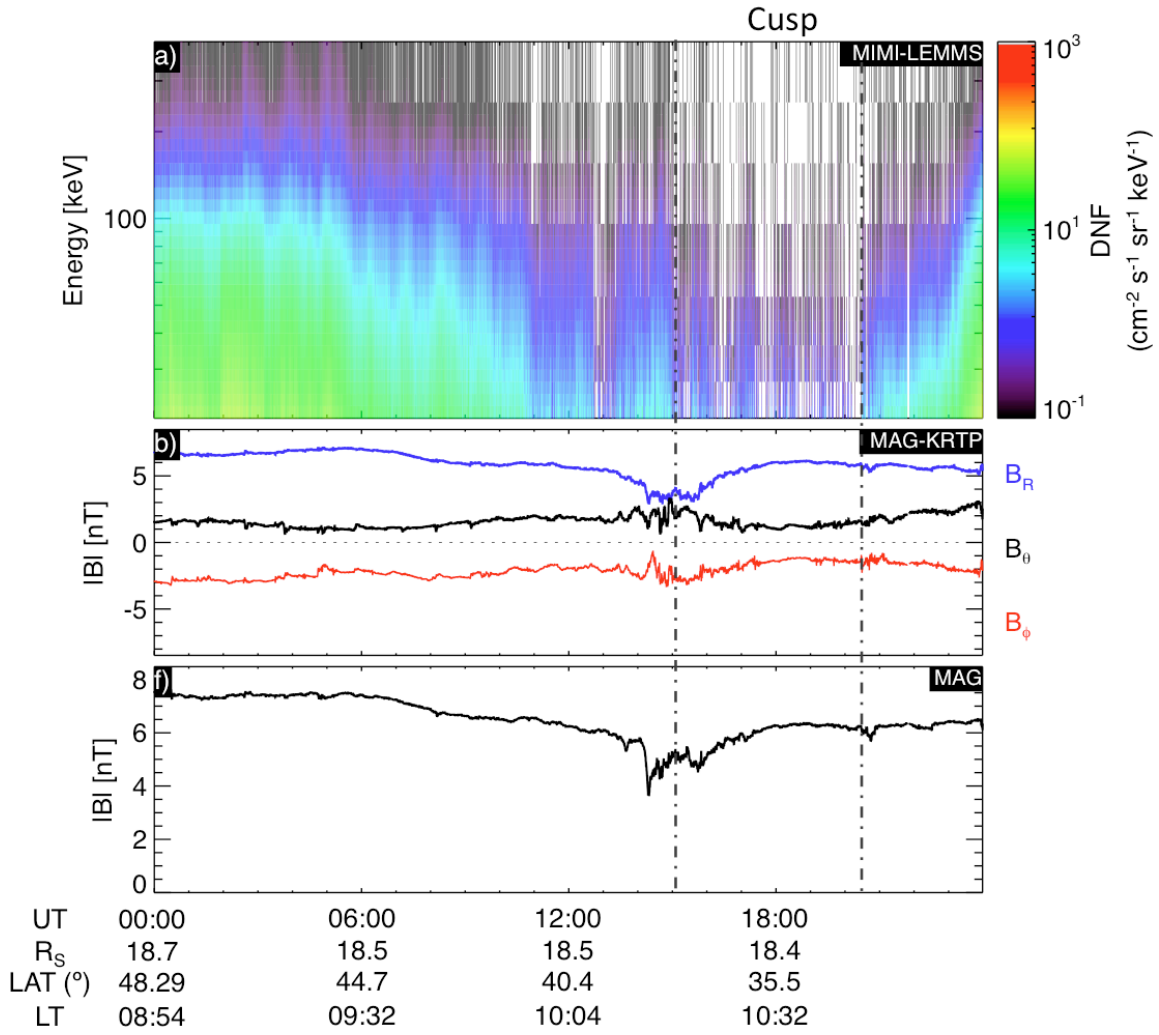

Figure S3. Cusp observations from the 17th of August 2013. The data are presented in the same format as Figure S2.

Text S2.

An example of the appearance of the ion energy-pitch angle dispersion in the energy-time spectrogram during the AUG08 event can be seen in the top panel of Figure S3 (IMS observations from anode 5). The bottom panel shows the corresponding pitch angle observed by anode 5 as the instrument actuates. It can be seen that as anode 5 observes lower pitch angles, the energy of the ions increases. This causes an `M' shaped signature in the ion data in the northern hemisphere. This is the same as the first terrestrial observations reported in *Burch et al.,* (1982) however they observed a `V' signature due to the pitch angle changing from 0º to 180º (also in the northern hemisphere). The observations (in FigureS3) at Saturn are inverted due to the oppositely orientated magnetic poles at Saturn, which results in the `V' signature to be upside down for these observations. The upside down `V' becomes an upside down `W' signature because the pitch angle look direction during these observations is from 0º to an alternating amplitude of 70º and 120º. Therefore, the instrument observes ions with pitch

angles of 0° twice for every time 120° is observed. This results in an `M' shaped signature. Observations in the southern hemisphere at Saturn would show a `W' signature with the same pitch angle coverage. The energy-latitude dispersion can also be seen in Figure S3, with the peak (at 0° pitch angles) and minimum (at 120° pitch angles in this observation) energies decreasing with time and latitude.

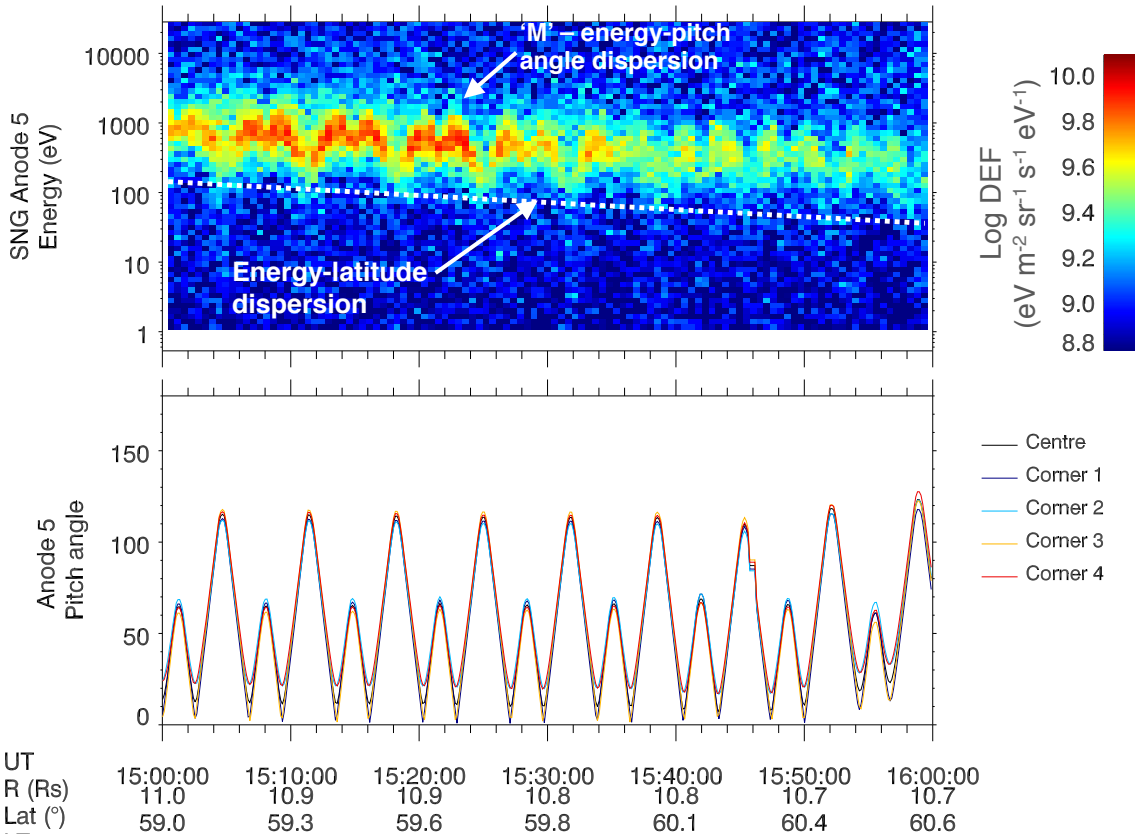

Figure S3. Energy-time spectrogram displaying the energy-pitch angle dispersion in the data during the 3AUG08 event. Top panel: CAPS-IMS ion observations from anode 5; bottom panel: the corresponding pitch angle observed by anode 5 as the instrument actuates. The baffle through which the ions enter to be detected by the instrument's anodes represents a rectangular surface. Therefore the pitch-angle of each corner of the anode's 'view' as well as the pitch-angle of the centre is shown in the bottom panel.

Text S3.

The binned results can be seen in Table S1, for the distance to the reconnection site. The values for 1FEB07, 16JAN07 and 21JAN09 (*Jasinski et al.,* 2014; *Arridge et al.,* 2016) are reproduced here for completeness. The errors shown here for 21JAN09 have been corrected and therefore differ than those presented by *Jasinski et al.,* (2014). For more information about the reconnection distance calculation please see *Arridge et al.,* 2016).

Also shown are the compositional measurements from CAPS-IMS in Table S2. Compositional data for 21JAN09 is not presented here for each dispersion, however *Jasinski et al.,* (2014) reported a values of 25.8±0.2% and 2.62±0.02% of the [m/q=2] to H^+ ratio for the magnetosphere and cusp respectively, similar to values presented here.

Date	Description	Time (UT)	Reconnection Distance Mean (R_S)	Reconnection Distance σ (R_S)
16JAN07	Cusp - 1st Dispersion - 'a'	10:05 – 11:21	50 ± 20	16
	Cusp / Mixed Layer -'b'	17:24	16 ± 3	—
	Cusp -'b'	16:03 – 17:20	26 ± 3	9
1FEB07	Cusp - 1st Dispersion	16:50 – 18:32	50 ± 20	15
	Cusp - 2nd Dispersion	01:26 – 02:43	37 ± 9	5
8MAR07	Cusp - 1st Dispersion	07:45 – 09:02	16 ± 1	2
	Cusp - 2nd Dispersion	09:02 – 10:02	15.6 ± 0.4	0.1
25MAY08	Cusp - 1st Dispersion	01:26 – 02:30	—	—
	Cusp - 2nd Dispersion	03:34 – 05:42	16 ± 3	4
	Cusp - 3rd Dispersion	05:43 – 07:50	—	—
24SEP08	Cusp	05:42 – 07:24	21 ± 5	—
23NOV08	Cusp - Bin 1	05:36 – 06:27	—	—
	Cusp - Bin 2	06:27 – 06:53	—	—
3AUG08	Cusp - Bin 1	14:47 – 16:06	32 ± 7	3
	Cusp - Bin 2	18:39 – 18:49	26 ± 8	–
	Cusp - Bin 3	18:50 – 19:30	—	—
	Cusp - Bin 4	20:47 – 22:04	—	—
21JAN09	Cusp - Bin 1	11:00 – 11:50	27 ± 5	8
	Cusp - Bin 2	11:50 – 12:45	39 ± 7	7
	Cusp - Bin 3	12:45 – 15:00	49 ± 6	6
	Cusp - Bin 4	15:00 – 17:00	51 ± 2	5
	Cusp - Bin 5	17:00 – 18:00	46 ± 4	10

Table S1.
Presented are the estimated distances to the reconnection site from energy-pitch angle dispersions. The binned values for 1FEB07 (and 16JAN07-a) for the distances to the reconnection site are taken from *Arridge et al.,* (2016), and for 21JAN09 are corrected from *Jasinski et al.,* (2014).

Date	Description	Time (UT)	Composition	
			W^+/H^+ (%)	$[m/q=2]/H^+$ (%)
16JAN07	Cusp - 1st Dispersion - 'a'	10:05 – 11:21	—	1.78 ± 0.03
	Magnetosphere	13:04 – 15:37	3.5 ± 0.2	10.3± 0.1
	Cusp / Mixed Layer -'b'	17:24	—	
	Cusp -'b'	16:03 – 17:20	—	7.42 ± 0.04
1FEB07	Cusp - 1st Dispersion	16:50 – 18:32	—	1.93 ± 0.04
	Magnetosphere	18:58 – 23:39	—	9.0 ± 0.3
	Cusp - 2nd Dispersion	01:26 – 02:43	0.42 ± 0.04	4.76 ± 0.03
8MAR07	Cusp - 1st Dispersion	07:45 – 09:02	0.93 ± 0.18	2.2 ± 0.56
	Cusp - 2nd Dispersion	09:02 – 10:02	—	1.5 ± 0.05
	Magnetosphere	11:06 – 14:01	4.7 ±1.2	8.3 ± 0.27
25MAY08	Cusp - 1st Dispersion	01:26 – 02:30	—	4.3 ±0.03
	Cusp - 2nd Dispersion	03:34 – 05:42	0.29 ± 0.02	3.6 ± 0.02
	Cusp - 3rd Dispersion	05:43 – 07:50	0.42 ± 0.40	2.1± 0.1
24SEP08	Magnetosphere	02:43 – 04:00	9.6 ± 5.6	16.9 ± 0.3
	Cusp	05:42 – 07:24	0.6 ± 0.5	2.1 ± 0.03
23NOV08	Magnetosphere	03:54 – 05:36	5.3 ± 0.4	15.7 ± 0.1
	Cusp - Bin 1	05:36 – 06:27	1.3 ± 0.2	3.1 ± 0.1
	Cusp - Bin 2	06:27 – 06:53	—	3.4 ± 0.1
3AUG08	Magnetosphere	05:26 – 07:34	32.6 ± 1.2	28.2 ± 0.1
	Cusp - Bin 1	14:47 – 16:06	0.97 ± 0.04	4.2 ± 0.03
	Cusp - Bin 2	18:39 – 18:49	—	2.4 ± 0.03
	Cusp - Bin 3	18:50 – 19:30	—	2.4 ± 0.03
	Cusp - Bin 4	20:47 – 22:04	0.67 ± 0.07	2.2 ± 0.03

Table S2. Presented is the composition of the ions in the magnetosphere adjacent to the cusp, and in the cusp itself, for water group ions (W$^+$) and ions with a mass-per-charge of 2amu/q (m/q=2), as a percentage ratio by number of ionised hydrogen (H$^+$).

References

Arridge, C., et al. (2016), Cassini observations of saturn's southern polar cusp, Journal of Geophysical Research: Space Physics, doi:10.1002/2015JA021957, 2015JA021957.

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